the principal observer, the cost of such observations would be small for each opportunity to observe, and for any given station the number of opportunities during the year would be few. The expense at any station for a year would probably not surpass $150, so that for $3,000 such observations could be scattered at 20 colleges over the States, with probable results far in excess in value over the cost.

A more instructive but more expensive method is that of pilot balloons carrying automatic registering instruments. This method of sounding the upper air was proposed by Le Verrier in 1784, and has within the last few years been repeatedly tried in France. In the last four months of 1892 M. Hermite sent up 13 such balloons, all of which reached an altitude of over 9 kilometers, or 6½ miles; and one sent up on March 21, 1893, must have reached an elevation of over 16 kilometers, or 10 miles. These balloons carry means for the automatic record of pressure and temperature, but the last-mentioned found so cold temperatures that for a considerable time the specially prepared ink could not perform its functions. They also carried a device for releasing and dropping cards, to enable the following of the course of the balloon; but this has not been successful, as the fuse which releases the cords is soon extinguished. In the ascent of March 21, out of 600 cards taken up only 400 were released, and of these only 5 or 6 were recovered. It is found, however, that the recovery of the balloon is much easier than had been expected, as a printed direction on the balloon itself leads to its recovery as soon as it falls into the hands of any intelligent person.

The difficulties in the way of these remarkably interesting explorations prove to be less than could have been expected; but there are many questions about them still unsettled. Under these circumstances it is not easy to make an estimate of the cost of systematic work in this direction. I have, however, asked Prof. H. A. Hazen to make the estimates for me. He has estimated approximately that a balloon to ascend to a height of 4 miles with a load of instruments of 20 pounds would cost $150 if made of silk and $200 if made of goldbeater's skin. For a balloon to ascend to the height of 10 miles he puts the corresponding prices at $600 and $800. The instrumental outfit would have to be prepared expressly and would be expensive. Probably the sum of $5,000 would permit of one such pilot balloon per week during the year to the height of 4 miles, and perhaps one per month to the greater height. The station selected for such observation should be near the middle of the continental area—say somewhere from Kansas to Manitoba.

BALLOONS WITH AERONAUTS.

The preceding methods, while they would give highly interesting and instructive results, are somewhat imperfect as means of obtaining all the information needed by meteorologists. Much better for this purpose would be systematic work by a meteorologist who should make the ascension himself. Evidence points to the conclusion that the cloud layer, and perhaps the upper cloud surface, is a region of especial activity in meteorological phenomena, but the facts on which such a conclusion could be verified are of such character that they would probably escape any automatic registry. Their record requires the presence of a trained meteorologist. These observations should be systematic, as the sporadic ones are of relatively little value. A meteorologist should ascend twice a day to a considerable height, and should keep this up through all kinds of weather and through the season. The elevation need not be great; probably the first 20,000 feet include the layer of air in which the meteorological phenomena which we call weather are active. At least the stratum of this thickness is far more important to us than all the rest of the depth of the atmosphere.

The cost of such a campaign would be considerable, but would vary with the material used, the care in using it, the position of the station, etc. I think a year's campaign of this sort could be gone through for an expense of $20,000.

In conclusion, it appears that a year's campaign could be made in the free air as follows:

To 3,000 feet (perhaps), with small balloons	$3,000
To 14,000 feet, with kites	10,000
To 20,000 feet, 52 pilot balloons	} 3,000
To 50,000 feet, 12 pilot balloons	}
To 20,000 feet, with aeronaut	20,000

The results to be obtained would be cheap at any of these prices, but the fourth method seems to me incomparably the best as well as the most certain. A year's campaign of this sort would add very greatly—more than in any other possible way in the same time—to the knowledge of meteorology and hence to the forecasting of the weather. There is no other way, I believe, in which this sum of money could be expended to the greater advantage of meteorology.

(NOTE.—Upon the reading of the above paper it was, upon motion of Mr. D. Torrey, unanimously resolved [by the Conference]:

"That it is the sense of this meeting that the experiments proposed by Mr. Harrington are likely to prove of public value in forecasting the weather, and that Congress should, in our judgment, make the necessary appropriation to have the experiments made as recommended by Mr. Harrington.")

EXTRACTS FROM THE ANNUAL REPORT OF THE SMITHSONIAN ASTROPHYSICAL OBSERVATORY.[1]

C. G. ABBOT, Director.

[Dated: Washington, D. C., June 30, 1914.]

Observations [*at Washington*].—Mr. Fowle has continued the difficult research on the transmission through moist air of radiations of great wave length, such, for instance, as those which bodies at the temperature of the earth emit most freely. He uses a very powerful lamp made up of a large number of Nernst electric glowers, and examines by the aid of the spectrobolometer the energy spectrum of the rays emitted by this lamp, first directly, and then, after the rays have traversed twice or four times a tube 200 feet long, containing air of measured humidity. During the past year Mr. Fowle has been dealing principally with rays of the very longest wave lengths of the terrestrial energy spectrum which moist air transmits. He has reached a wave length of about 18 microns, which is about 25 times the longest wave length visible to the eye, and about three and one-half times the wave length of the solar rays investigated by this observatory in the years 1890 and 1900.

A great number of difficulties are met with. In the first place, great sensitiveness of the bolometer is required, owing to the feebleness of these rays. Attempts to use a vacuum bolometer have consumed much time, but not yet with entire success. Full success in this

[1] *Extracted from* Appendix 5 of Smithsonian Institution. Report of the Secretary for the year ending June 30, 1914. Washington, 1914. iii, 117 p. 4 pl. 1 fig. 8° (Publication 2317.)

seems now probable. In the second place there is great difficulty in determining the amount of radiation lost in the optical train required to reflect the beam to and fro through the long tube. A principal difficulty in this matter arises from the fact that the lamp and its surroundings are unequally hot at different parts, for this has led to different degrees of loss at different wave lengths. This last source of error is so obscure that it escaped our attention for a long time and has required the observations to be repeated after results worthy of publication had, as it was thought, been reached. These and a host of other difficulties have delayed the research, but great hope is now felt that satisfactory results will be ready for publication in another year.

Computations.—Mr. Fowle has continued the study of the effect of terrestrial water vapor on the Mount Wilson solar observations and has published several valuable papers on it. An interesting result is, that after determining and correcting for the effect of atmospheric water vapor on the transmission of solar rays the coefficient of atmospheric transparency determined at Mount Wilson when combined with the barometric pressure after the manner indicated by Lord Rayleigh's theory of gaseous scattering of light, yield the value 2.70 billion billion as the number of molecules at standard pressure and temperature in a cubic centimeter of gas. Prof. Millikan, by a wholly independent kind of reasoning, has derived from electrical experiments the value 2.705 billion billion. The close agreement found is a strong confirmation of the accuracy of our determinations of atmospheric transparency, and accordingly tends to increase confidence in our determination of the solar constant of radiation.

Sky radiation instruments.—The director and Mr. Aldrich have devoted much time to the design and testing of apparatus for measuring the scattered radiation of the sky by day. What is desired is an instrument exposing horizontally an absorber of radiation in such a manner that the rays of the entire visible hemisphere of the sky would be received upon it, all rays not of solar origin would be excluded by a suitable screen, and the total energy of the scattered sky radiation originally emitted by the sun would be measured accurately. This is a more difficult problem than the measurement of the direct solar radiation, and it is unlikely that quite as high precision can be attained with the sky radiation instrument as with the pyrheliometers used for measuring direct solar radiation. From experiments with several instruments of the kind which have been constructed in the observatory shop by Mr. Kramer and tested by Messrs. Abbot and Aldrich it now seems probable that the sources of error can be so far eliminated that sky radiation measurements accurate to about 2 per cent will be made. An instrument embodying what are thought to be the final improvements of design is now under construction, and it is hoped it will be used a great deal in the coming year.

Balloon pyrheliometers.—Still more time has been devoted by Messrs. Abbot, Aldrich, and Kramer to the reconstruction and testing of balloon pyrheliometers. Mention was made in last year's report of the proposed measurements of solar radiation by apparatus attached to sounding balloons and raised to great elevations. As stated below, the first trials in August, 1913, while unexpectedly successful in many ways, did not enable us to obtain measurements above the elevation of about 14,000 meters, or 45,000 feet. At this elevation the mercury froze in the thermometers. Also, the clockwork proved not sufficiently accurate for best results. Still the results obtained were so promising that it was thought well to repeat the experiments.

Accordingly, the 5 balloon pyrheliometers were reconstructed. Excellent French clocks were substituted for those used in 1913, and many improvements of the instruments were introduced. Two devices were employed to prevent the freezing of the mercury in the thermometer. In some instruments water jackets, having numerous interior copper bars to act as heat conductors, were arranged. In these it was hoped to make available the latent heat of freezing of the water and thus to prevent the surroundings of the pyrheliometric apparatus from descending far below the freezing point of water. In other instruments electrical temperature regulators were provided. Many experiments were tried to obtain a constant, powerful, and very light electric battery for this purpose. At length a modification of the Roberts cell was designed in which individual cells weighing 20 grams (three-fourths ounce) would furnish a constant potential of 1.3 volts and yield a nearly constant current of about 0.5 ampere for nearly two hours. The internal resistance of the cells was only about 0.3 ohm. Barometric elements were made to record on the same drum that recorded radiation. One instrument was constructed to be sent up at night, so as to show if any unexpected phenomena occurred when the instruments were being raised apart from those due to the sun. Many tests of the instruments were made at different temperatures and pressures, and while immersed in descending air currents comparable to those anticipated to attend the flights.

Silver-disk pyrheliometers.—As in former years, a number of silver-disk pyrheliometers were standardized at the Observatory and sent out by the institution to several foreign Government observatories.

Mount Wilson expedition of 1913.—Mr. Aldrich went to Mount Wilson early in July, 1913, and carried on there solar constant measurements until September, when he was joined and then relieved by Mr. Abbot, who continued the observations until November. An expedition at the charge of the private funds of the Smithsonian, and under the direction of Mr. A. K. Ångström, was in California during July and August for the purpose of measuring nocturnal radiation at different altitudes, ranging from below sea level to the summit of Mount Whitney, 4,420 meters (14,502 feet). Mr. Aldrich cooperated as far as possible with this expedition.

Balloon pyrheliometer.—At the same time a cooperating expedition from the United States Weather Bureau[3] made ascents of captive and free balloons in order to determine the temperature, pressure, and humidity at great elevations, for use in reducing Mr. Ångström's observations. Advantage was taken of the opportunity to send up special pyrheliometers for measuring solar radiation at great altitudes. These experiments, which were made jointly by Mr. Aldrich, and Mr. Sherry of the Weather Bureau, were referred to by anticipation in last year's report. Five balloon pyrheliometers were sent up from Santa Catalina Island. All were recovered with readable records. One instrument unfortunately lay in a field about six weeks before recovery, and parts of its record referring to the higher elevations were obliterated, but it yielded the best results of any up to about 8,000 meters. Two of the instruments unfor-

[3] See MONTHLY WEATHER REVIEW, Washington, 1914, 42: 410-426.

tunately were shaded by cirrus clouds until after the mercury froze in their thermometers. The highest elevation at which a radiation record was obtained was about 14,000 meters, or nearly 45,000 feet. As stated in last year's report, no results indicating that values of radiation exceeding our solar constant value (1.93 calories) are obtainable by pyrheliometric measurements at any elevation, however high, appear from these balloon pyrheliometer experiments. In view of the proposed repetition of the experiments with improved apparatus no further statement of these preliminary results is necessary here.

The tower-telescope work.—As stated in former reports, investigations were carried on at Washington during the years 1904–1907 to determine the distribution of the sun's radiation along the diameter of the solar disk. It was shown by this work, in accord with results of earlier observers, that the edge of the solar disk is much less bright than the center, and that this contrast of brightness is very great for violet and ultraviolet rays, but diminishes steadily with increasing wave lengths and becomes very slight for red and especially for infrared rays. * * *

The measurements were continued at Washington on all suitable days in the hope that some fluctuation of this contrast of brightness between the edge and center of the solar disk would be disclosed. It seemed probable that there might be such fluctuations associated with the irregular variability of the total solar radiation. It proved, however, that such fluctuations, if existing, were of so small an order of magnitude that it was not certain whether they were really shown by the observations at Washington, hampered as these were by variable transparency of the air.

When the observing station was erected on Mount Wilson in 1908, provision was made for a tower telescope designed to continue this research. When in 1911 and 1912 the Algerian expeditions confirmed the sun's variability, added interest was felt in the proposed experiments. Accordingly, the tower, 50 feet in height, was completed in 1912. Not sufficient funds were available to equip the tower telescope, but Director Hale, of the Mount Wilson Solar Observatory, kindly loaned considerable apparatus, and with this and some apparatus which remained from eclipse expeditions, and by using anything available, as, for instance, a trunk of a tree for a mirror support at the top of the tower, Messrs. Abbot and Aldrich succeeded in getting arranged on the tower a reflecting telescope of 12 inches aperture and 75 feet focus, all ready for observations by September 9, 1913. Then and thereafter solar constant measurements were supplemented by determinations of the distribution of radiation along the sun's diameter on each day of observation. These determinations are made in seven different wave lengths on each day, ranging from 0.38μ in the ultraviolet to 1.1μ in the infra-red. Fortunately, the definition of the tower telescope proves to be very good. There is slight change of focus during the several hours of observing, and the "seeing" seems not to deteriorate much up to 10 a. m., at which time the observations are generally concluded.

About 45 days of simultaneous observations of the "solar constant" and of the distribution of radiation over the sun's disk were secured in 1913. The results appear to indicate a variability in both phenomena and a distinct correlation of the two in point of time. It is indicated that when in course of its short-period irregular variation the solar radiation increases, there occurs simultaneously a diminution of the contrast between the edge and center of the sun's disk. A change of brightness of about 1.5 per cent was found to occur at 95 per cent out on the solar radius accompanying a change of 6 per cent in the solar radiation. On comparing the mean of all results obtained in 1913 with the mean of all obtained in Washington in 1906–7, it appears that there was distinctly less contrast of brightness between the edge and center of the sun's disk in 1913 than in 1907. We have reason, however, to believe that there was distinctly a greater total solar radiation in 1907 than in 1913. This result, compared with the result stated above, indicates a difference of character between the long-period fluctuations of the sun and its short-period irregular fluctuations. The changes of contrast found, however, agree in this, that whether from day to day in 1913, or as between 1913 and 1907, the violet or shorter wave-lengths change in contrast more than the red or longer wave lengths. * * *

THE AMERICAN METEOR SOCIETY.

By Prof. CHARLES P. OLIVIER.

[Dated: Charlottesville, Va., December 25, 1914.]

The American Meteor Society was first organized in the latter part of 1911, and from that time to the present has endeavored to stimulate interest in this much neglected branch of astronomy.

As must necessarily be the case, most of its members are amateurs, but there are several professional astronomers also enrolled. At the present time it contains about 20 members, the larger part being also members of the Society for Practical Astronomy, whose "Meteor section" forms far the most active group of our workers.

The purpose of the organization is to stimulate interest in observing and recording meteors along carefully planned and uniform lines, to collect this data at a central office, and to have the results computed and published in scientific form.

Circulars are furnished describing our methods and blank forms for the records are sent free on application. Also prospective members are advised where to secure suitable maps and anything else they may desire. All persons interested in this subject are urged to join us and are assured that they will receive full credit for any work submitted. The results from 1911 to 1913, inclusive, have been carefully worked up and printed as volume 2, part 4, of the publications of the Leander McCormick Observatory of the University of Virginia. In all, 126 parabolic orbits of meteor streams and many other results of interest were obtained from the 2,800 meteors there discussed. We would be very glad to secure any unpublished meteor records of any year whatever and to undertake their discussion and reduction. All communications and inquiries are to be addressed to Charles P. Olivier, Leander McCormick Observatory, University of Virginia. As scientific work in Europe is at present so greatly hindered, it is especially hoped that American observers will do more than their share during 1915 in observations of meteors.

[See also the MONTHLY WEATHER REVIEW, January, 1913, 41: 162.]